12.0 DEVELOPMENT AND SCREENING OF ALTERNATIVES

The general response actions and the process options that remain for consideration following the screening process in Sections 10.0 and 11.0 are assembled to form definitive RA alternatives in this section. The alternatives are designed to address the specific site requirements for aquifer remediation. The RA alternatives have been assembled according to the guidelines provided in the Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA (EPA 1988a).

This section presents the detail of the development and screening of alternatives. Prior to the development of alternatives, extraction scenarios were developed to evaluate groundwater extraction. Consequently, the development of extraction scenarios is presented before the development and screening of alternatives.

12.1 DEVELOPMENT OF EXTRACTION SCENARIOS

This section describes nine extraction scenarios that were simulated using the project flow model. The extraction scenarios were simulated for the purpose of comparing the efficiency and feasibility of remediation extraction systems for the Muscoy Plume OU.

This section is divided into three subsections: (1) a brief description of the project flow and plume capture models, (2) the rationale for the selection of extraction regions and extraction scenarios, and (3) the details and results of each extraction scenario.

12.1.1 Project Flow Model and Plume Capture Model

The project flow model serves as the basis for the extraction scenario simulations. Development of the project flow model was described in Subsection 6.4. The groundwater flow model was calibrated for steady-state and transient-state conditions present in the Muscoy Plume OU.

The steady-state flow model was simulated and calibrated for the time period between January 1982 to December 1985. The transient-state flow model was simulated and calibrated for the time period between January 1986 to December 1990. The input data and boundary conditions, resulting from the calibration of the steady-state flow model, were used as the initial conditions for the transient-state flow model. Some of the input data and boundary conditions (i.e., transmissivities, recharge values) were refined in order to calibrate the transient-state flow model. The calibrated transient-state flow model then became the project flow model, which was used for simulation of the extraction scenarios. The measured recharge, streamflow, pumpage, and head values for this time period were used in the extraction scenario simulations.

MODFLOW (McDonald and Harbaugh 1988) was the groundwater flow program used to simulate the groundwater flow for the model area. PATH3D (Zheng 1991) was used as post-processor for the MODFLOW output data. PATH3D, a groundwater path and travel-time program, was used for the evaluation of contaminated plume captured by the extraction wells. PATH3D utilized the input data and unformatted head files of MODFLOW simulations to:

- Create contours of the calculated heads;
- Simulate the pathlines of imaginary particles placed in various areas of the Muscoy plume; and
- Delineate capture-zones for each extraction scenario.

SURFER (Golden Software, Inc. 1990) is a graphics program, which utilizes the head contour files created by PATH3D to produce plots displaying the head contours, pathlines of imaginary particles, and locations of the extraction areas.

12.1.2 Extraction Regions and Extraction Scenarios

A total of nine extraction scenarios were simulated during predictive modeling. Each extraction scenario consisted of pumping from one or a combination of three extraction regions. For modeling purposes, the extraction regions were subdivided into extraction areas that represented either individual extraction wells or groups of extractions wells. It should be noted that the extraction areas were developed for modeling purposes only. The exact locations and number of extraction wells will be determined during remedial design. The extraction regions for the Muscoy Plume OU consisted of the following:

- Municipal supply wells No. 1 and No. 2 near 19th and Flores Streets (19th Street wellfield);
- Baseline Feeder wells near 9th Street and Mt. Vernon Avenue, and 9th and Perris Streets (Baseline Feeder wellfield); and
- An area perpendicular to the long axis of the contaminant plume, midway between the 19th Street wellfield and the Baseline Feeder wellfield.

The 19th Street wellfield was chosen as an extraction region to evaluate the effectiveness of an existing groundwater treatment plant as part of a remediation strategy. The Baseline Feeder wellfield was chosen to represent an extraction region to evaluate how pumping from this region wells might affect extraction from the leading edge of the contaminant plume. The downgradient edge of the groundwater contaminant plume was chosen as an extraction region for the main purpose of preventing further downgradient contaminant migration.

Two regions were also chosen to represent injection of treated groundwater. The injection regions were used in extraction scenario no. 9 to evaluate aquifer injection as an end-use remedial alternative. One injection region consisted of four areas along the western edge of the contaminant plume; this region was chosen to evaluate injecting the treated groundwater west of the contaminant plume. The second injection region consisted of four areas along the eastern edge of the contaminant plume; this region was chosen to evaluate injecting treated groundwater east of the contaminant plume.

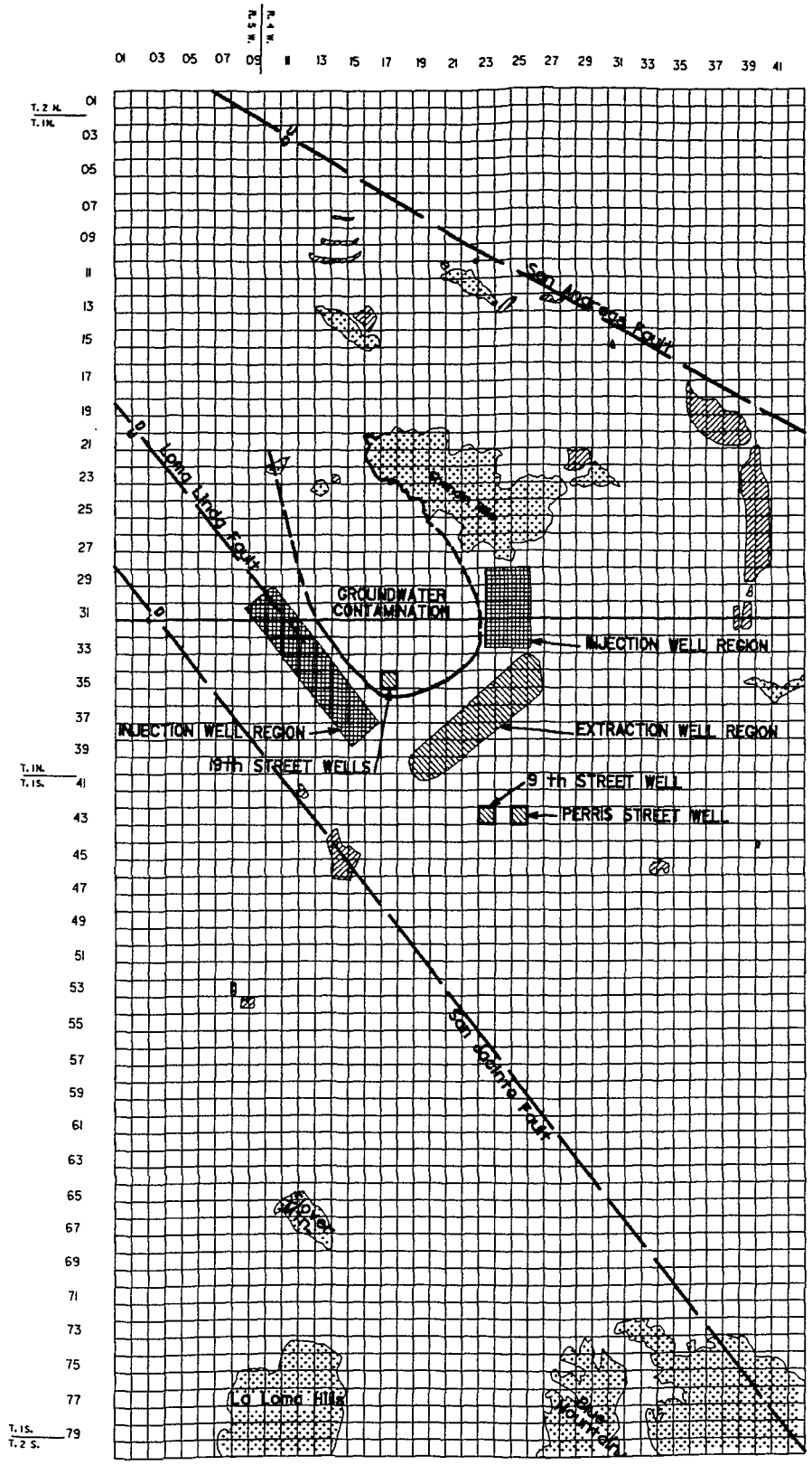
It should be noted that the main purpose for considering groundwater injection was to evaluate an end-use alternative. Injection scenarios were not optimized during the current modeling effort. If the injection end use alternative becomes part of the selected remedy, additional evaluation to optimize injection well locations and injection rates must be performed.

The nine extraction scenarios were:

- Extraction scenario no. 1 - simulated for a duration of 35 years using the 19th Street and Baseline Feeder wellfields;
- Extraction scenario no. 2 - simulated for a duration of 35 years using the 19th Street wellfield;
- Extraction scenario no. 3 - simulated for a duration of 35 years using three extraction areas located in the downgradient edge of the plume and the 19th Street wellfield;
- Extraction scenario no. 4 - simulated for a duration of 35 years using three extraction areas located in the downgradient edge of the plume and the 19th Street wellfield;
- Extraction scenario no. 5 - simulated for a duration of 35 years using four extraction areas located at the downgradient edge of the plume and 19th Street wellfield;
- Extraction scenario no. 6 - simulated for a duration of 35 years using four extraction areas located at the downgradient edge of the plume;
- Extraction scenario no. 7 - simulated for a duration of 35 years using four extraction areas located at the downgradient edge of the plume (constant pumping rates) and Baseline Feeder wellfield;
- Extraction scenario no. 8 - simulated for a duration of 35 years using four extraction areas located at the downgradient edge of the plume (seasonally varied pumping rates) and Baseline Feeder wellfield; and
- Extraction scenario no. 9 - simulated for a duration of 35 years using four extraction areas located at the downgradient edge of the plume, and eight injection areas along the east and west edges of the plume.

The locations of the extraction areas are shown in Figure 12-1. Table 12-1 lists extraction scenario parameters. Extraction scenario no. 1 was simulated to evaluate the effectiveness of plume capture due to combined extraction from existing 19th Street and Baseline Feeder wellfields. This extraction scenario was also known as the No Action scenario. Extraction scenario no. 1 was used to:

- Estimate the position of the Muscoy OU plume 35 years from January 1986; and
- Evaluate the influence of existing municipal supply wells within the Muscoy Plume OU and the possibility of their use as extraction areas for the Muscoy Plume OU.



LEGEND	
	Fault
	Bedrock Outcrop
	Precolation Basin or Pond
	Extraction Regions
	Injection Regions

Existing Municipal Wells

Well Name		Grid Numbers	
19 th Street	#1	35	17
19 th Street	#2	35	17
9 th Street		43	23
Perris Street		43	25

Note: Only The Municipal Wells Listed Above Are Used Along With New Extraction Wells For Development Of Extraction Scenarios

N

0 1 2

SCALE IN MILES

FIGURE 12-1

LOCATION OF EXTRACTION AND INJECTION AREAS

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Table 12-1

EXTRACTION SCENARIOS FOR MUSCOY PLUME OU

Extraction Scenario	Extraction Area	Pumping Rate	Total Pumping (gpm)	Results
No. 1 (Run 57A)	19th St. No. 1 and No. 2 wells Perris St. well 9th St. well	Each @ 2000 gpm from 01/91 onward. 4000 gpm from 01/91 onward. 4500 gpm from 01/91 onward.	12,500	A number of the introduced imaginary particles were removed by 19th St., Perris St. and 9th St. wells. A few imaginary particles near the San Jacinto Fault boundary and many imaginary particles introduced north of Perris St. and 9th St. wells were not captured.
No. 2 (Run 56A)	19th St. No. 1 and No. 2 wells	Normal (or actual) pumping rates from 01/86 onward and repeated in 5-year cycles.	--	Most imaginary particles were not captured.
No. 3 (Run 58D)	19th St. No. 1 and No. 2 wells 3 new extraction wells	Each @ 1500 gpm from 01/91 onward. 1000, 1500 & 1500 gpm.	7,000	Most of the introduced imaginary particles were removed except a few near south of the extraction well cluster, and a few particles escaped through the space between 2 new extraction wells.

Table 12-1 (Cont'd.)

EXTRACTION SCENARIOS FOR MUSCOY PLUME OU

Extraction Scenario	Extraction Area	Pumping Rate	Total Pumping (gpm)	Results
No. 4 (Run 58E)	19th St. No. 1 and No. 2 wells 3 new extraction wells	Each @ 1500 gpm from 01/91 onward. 1000, 2000 & 1000 gpm.	7,000	Most of the introduced imaginary particles were removed except a few near south of extraction well cluster, and one particle north of extraction well cluster.
No. 5 (Run 59D)	19th St. No. 1 and No. 2 wells 4 new extraction wells	Each @ 1500 gpm from 01/91 onward. 1000, 1500, 1000 & 1000 gpm.	7,500	Only a few of the introduced imaginary particles were removed. A few in the south of and in the north of extraction well cluster escaped. Also, a few imaginary particles escaped between the four extraction wells.
No. 6 (Run 59J)	4 new extraction wells	1500, 1500, 1700 & 1500 gpm.	6,200	All the introduced imaginary particles were captured by the extraction wells.
No. 7 (Run 60A)	4 new extraction wells Perris St. well and 9th St. well	1500, 1500, 1700 & 1500 gpm. Normal pumping rate from 01/91 through 12/93. Normal yearly pumping rate of 93 was repeated every year from 01/94.	7,417 - 10,770	All the introduced imaginary particles were captured by the extraction wells. Plume capture in extraction scenario no. 6 was not affected by pumping from the Baseline Feeder wellfield.

Table 12-1 (Cont'd.)

EXTRACTION SCENARIOS FOR MUSCOY PLUME OU

Extraction Scenario	Extraction Area	Pumping Rate	Total Pumping (gpm)	Results
No. 8 (Run 60B)	4 new extraction wells Perris St. well and 9th St. well	Seasonally varying pumping in each quarter of a year with maximum pumping during 4th quarter @ 1500, 1500, 1700 & 1500 gpm. Normal pumping rate from 01/91 through 12/93 Normal yearly pumping rate of 93 was repeated every year from 01/94	5,495 - 10,770	Most of the introduced imaginary particles were captured except one particle south of and north of the extraction well cluster. One particle escaped between the four extraction wells.
No. 9 (Run 61C)	4 new extraction wells 8 new injection wells	1500, 1500, 1700, & 1500 gpm 775 gpm for each injection well	6,200 (pumping) 6,200 (injection)	All the introduced imaginary particles were captured by the extraction wells. An end-use alternative involved injecting treated groundwater in two injection regions.

Notes:
- All the runs were simulated for a period of 35 years starting from January 1986 through December 2020.
- New extraction wells were assumed to begin pumping from 6th year of simulation (i.e., pumping in extraction wells simulated for 30-year period starting from January 1991 through December 2020).
- All the extraction scenarios included normal (or actual) pumping from 19th St. No. 1 and No. 2 wells for first 5-year period between January 1986 through December 1990
- The Baseline Feeder wellfield includes Perris St. and 9th St. City of San Bernardino wells.
- Total pumping represents combined pumping rates from all extraction areas in a scenario. It also represents the constant pumping rate at any time starting from January 1991.

Table 12-1 (Cont'd.)

EXTRACTION SCENARIOS FOR MUSCOY PLUME OU

- The range of total pumping shown for extraction scenarios 7 and 8 represents seasonal fluctuations during quarters of a year starting in 1993. Maximum pumpage rates occur during the fourth quarter and minimum pumpage rates occur during the first quarter.
- See Figure 12-1 for the location of the extraction area.

Extraction scenario no. 2 was simulated for 35 years using just the existing water-supply wells in the site, including 19th Street wellfield but excluding the Baseline Feeder wellfield. Extraction scenario nos. 3 through 8 were simulated to determine the optimal extraction rate from the new extraction wells and the 19th Street and the Baseline Feeder wellfields. These scenarios also intended to evaluate the optimal location of the new extraction well areas. The new extraction well areas were located in the downgradient edge of the Muscoy Plume OU.

In the case of extraction scenario nos. 2 through 6, several simulations were made before the final simulation for each extraction scenario was achieved. A description of objectives, data, procedures and results for each extraction scenario are found in Sections 4.0 through 12.0 of Appendix 6. The results of the extraction scenarios are presented below.

12.1.3 Results of the Extraction Scenarios

Computer programs for the simulation of each extraction scenario were executed as follows:

- MODFLOW was run for each extraction scenario to simulate flow conditions of 35 years (or 140 stress periods) starting from January 1986 to December 2020.
- The results from MODFLOW run were used as input to run PATH3D© to create imaginary particle pathlines.
- The output files from PATH3D© were used in SURFER® to produce plots of head contours, pathlines of imaginary particles, and locations of extraction areas.

To create imaginary particles, three sets of imaginary particles (a total of 54) were used in PATH3D©. Set No. 1 contained seventeen imaginary particles that were placed near the northern portion of the Muscoy Plume OU along a northeast-southwest transect. Set No. 2 contained eighteen imaginary particles that were placed approximately half-way between the northern portion of the Muscoy Plume OU and the 19th Street wellfield along a northeast-southwest transect. Set No. 3 contained 19 particles that were placed just south of the 19th Street wellfield along a northeast-southwest transect. Appendix 6 lists locations of the imaginary particles.

The pathline of an imaginary particle produced by PATH3D© represents movement of groundwater in the aquifer with time. Since the contaminants (TCE and PCE) move with the groundwater, the imaginary particle pathline also represents the movement of contaminants in the aquifer with time. Therefore, the pathlines of the 54 imaginary particles placed, as described before, in the plume represent the movement of contaminants in the Muscoy Plume OU. Effectiveness of an extraction scenario was evaluated based on the capture of imaginary particles by the extraction wells. Pumping details and results of the extraction scenarios are presented on the following pages.

The discussion of extraction scenario no. 1 is presented in Subsection 6.4.2.

Extraction Scenario No. 2

This extraction scenario was simulated using the existing water-supply wells including the 19th Street wellfield (No. 1 and No. 2 19th Street wells). The pumping rate used for the 19th Street wellfield was as follows:

- For the 5-year period between January 1986 through December 1990, actual (normal) pumping rates were used; and
- For the next 30 years, January 1991 through December 2020, the actual 5-year pumping rates were repeated every 5 years. For the purpose of this extraction scenario, no pumping from the Baseline Feeder wellfield was assumed.

Figures 12-2 and 12-3 show the head contours and pathlines of the imaginary particles for layers 1 and 2, respectively. A few of the particles were captured by existing wellfields. Most of the particles were not captured.

Extraction Scenario No. 3

This extraction scenario consisted of extraction from the 19th Street wellfield and three extraction areas located near the downgradient edge of the plume. The extraction from the 19th Street wellfield was as follows:

- For the 5-year period between January 1986 to December 1990, normal pumping rates were used; and
- For the next 30 years, constant daily pumping of 1500 gpm from each of the 19th Street No. 1 and No. 2 wells was used.

The extraction in the three other extraction areas were:

- No pumping the first 5-year period; and
- For the next 30 years, constant daily pumping of 1000, 1500, and 1500 gpm from the three extraction areas.

Figures 12-4 and 12-5 show the head contours and pathlines of imaginary particles for layers 1 and 2, respectively. Most of the imaginary particles were captured by the three extraction areas and the 19th Street wellfield. But a few imaginary particles south of the three extraction areas were not captured. Also, a few particles escaped through the space between two extraction areas.

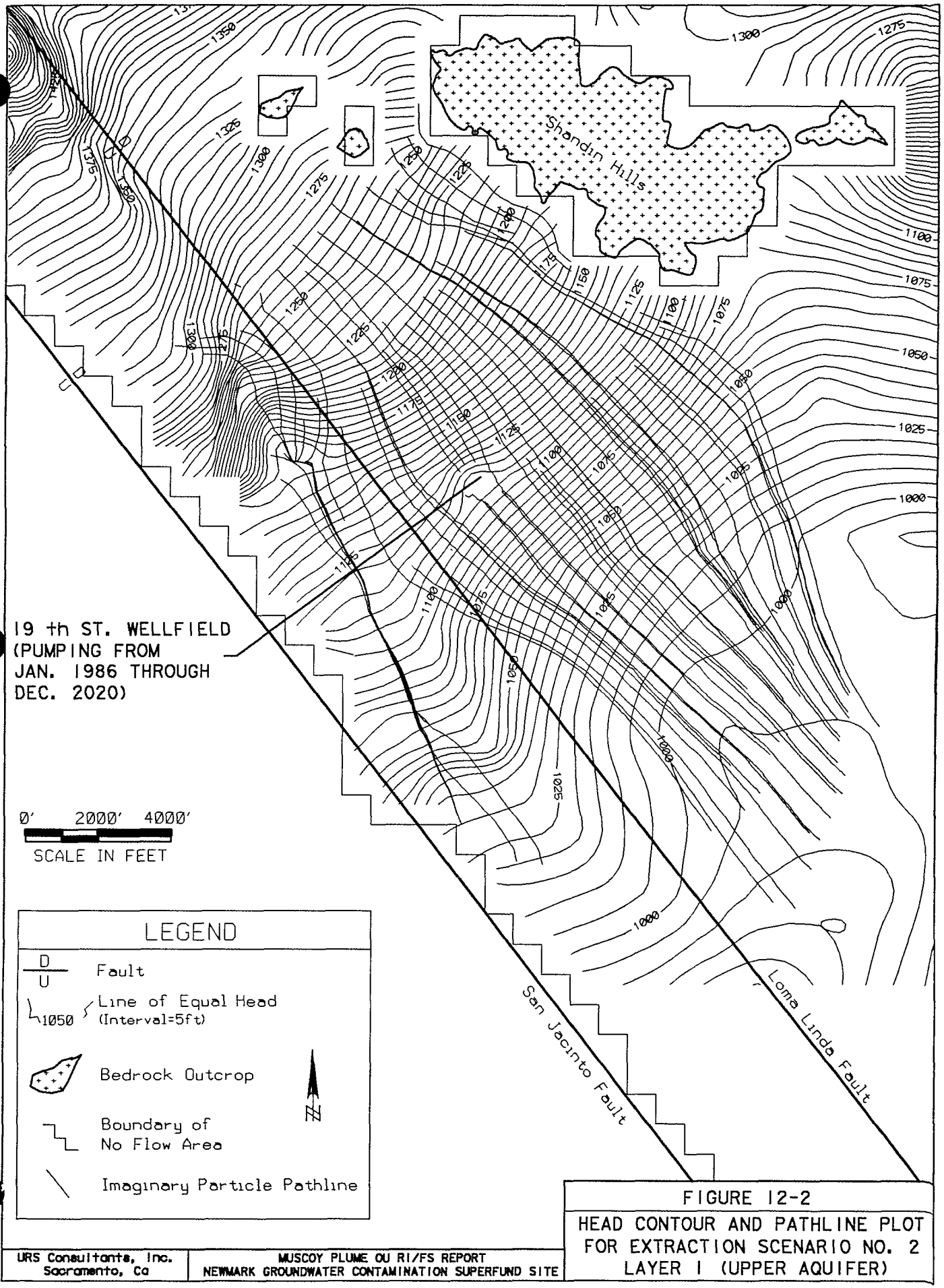

FIGURE 12-2

HEAD CONTOUR AND PATHLINE PLOT FOR EXTRACTION SCENARIO NO. 2 LAYER 1 (UPPER AQUIFER)

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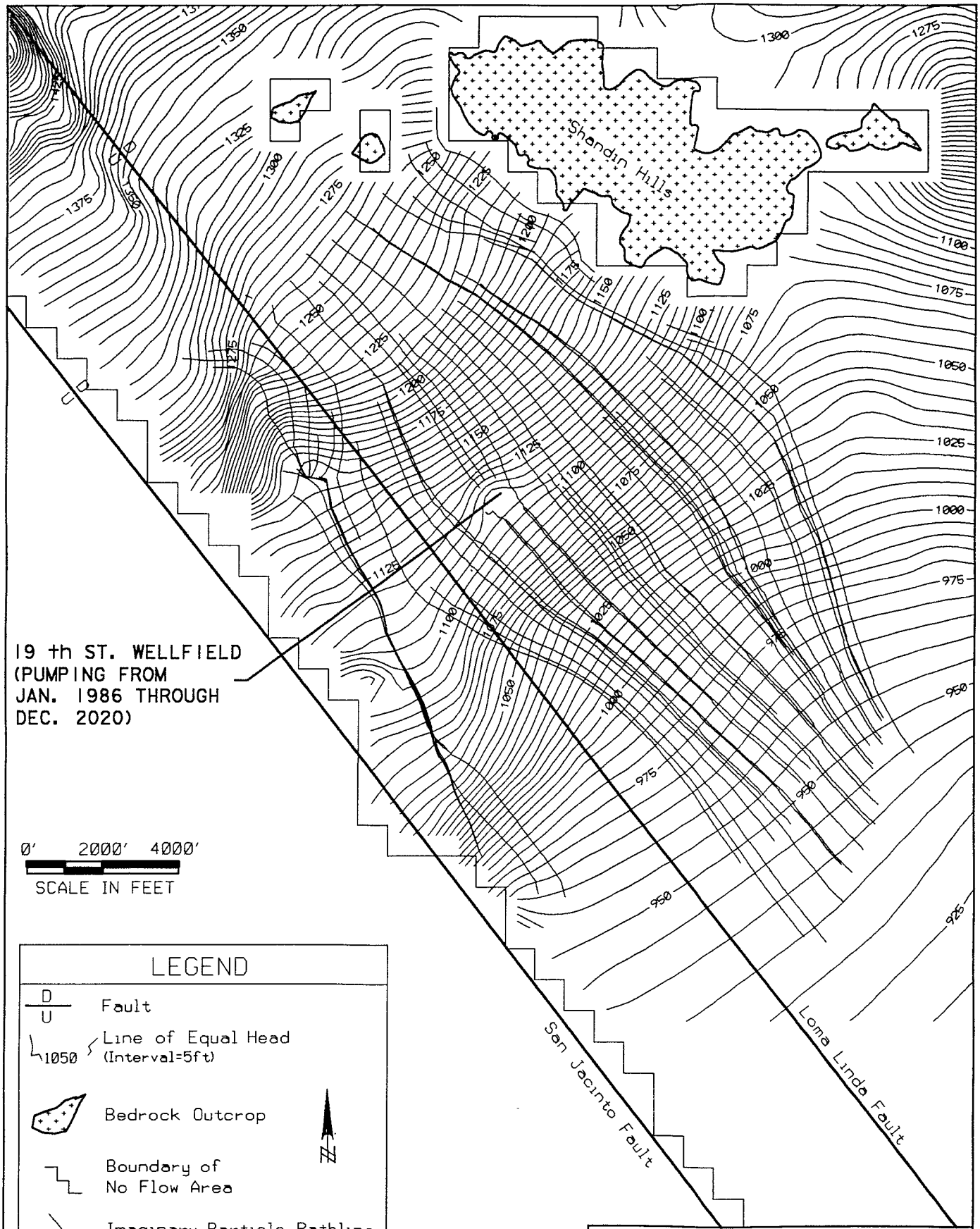

FIGURE 12-3

HEAD CONTOUR AND PATHLINE PLOT FOR EXTRACTION SCENARIO NO. 2 LAYER 2 (LOWER AQUIFER)

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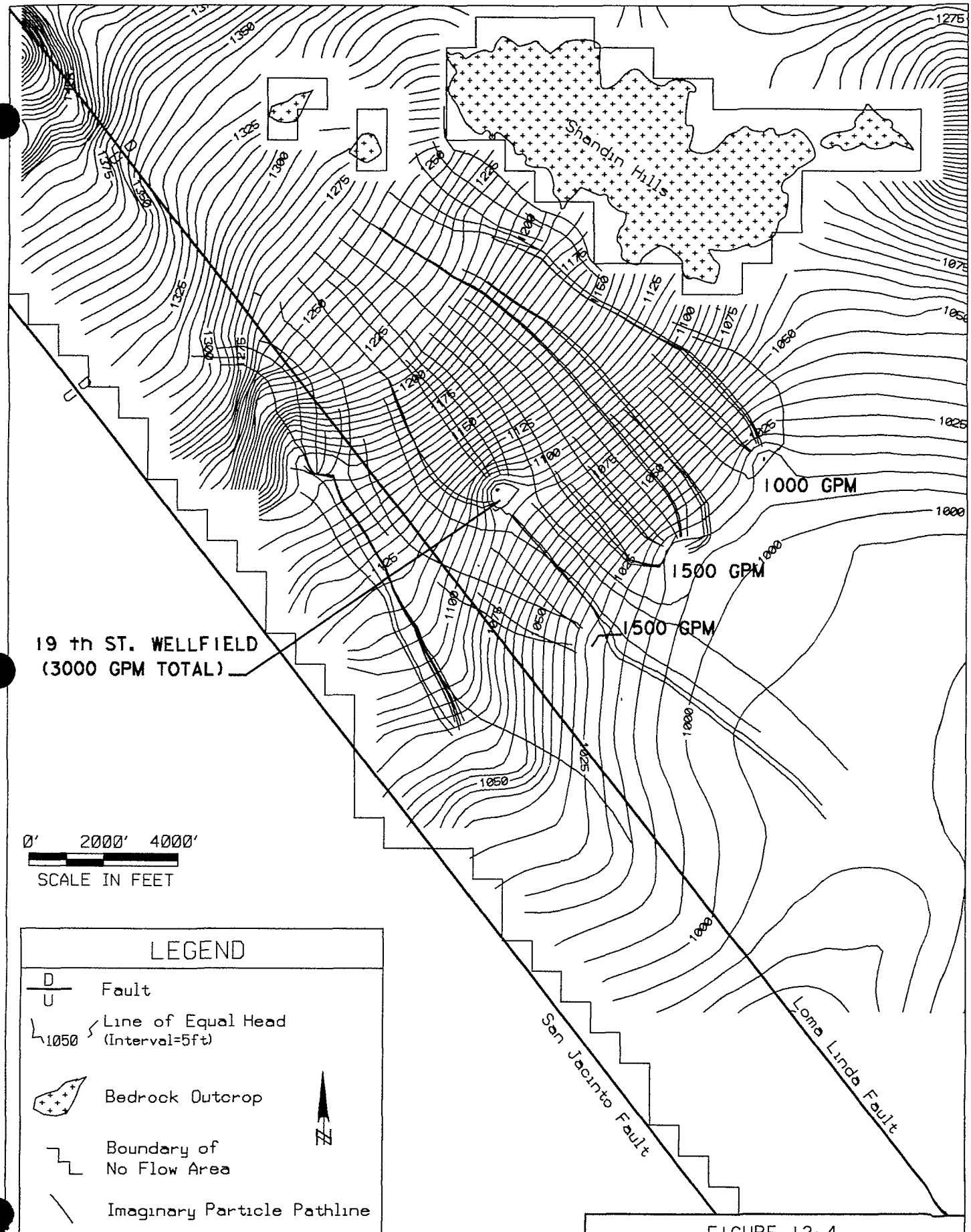

FIGURE 12-4

HEAD CONTOUR AND PATHLINE PLOT FOR EXTRACTION SCENARIO NO. 3 LAYER 1 (UPPER AQUIFER)

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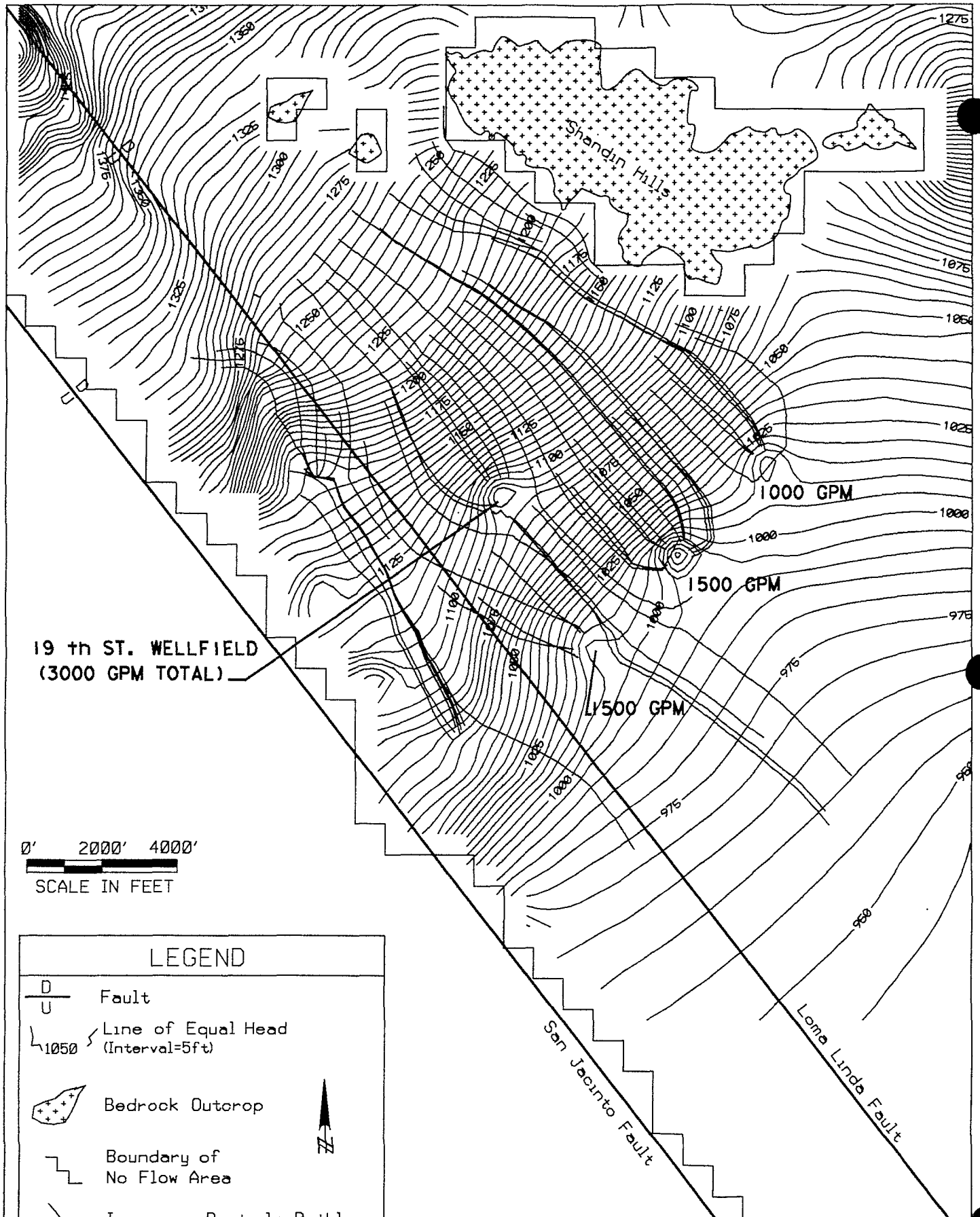

FIGURE 12-5

HEAD CONTOUR AND PATHLINE PLOT FOR EXTRACTION SCENARIO NO. 3 LAYER 2 (LOWER AQUIFER)

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Extraction Scenario No. 4

This extraction scenario consisted of extraction from the 19th Street wellfield and three extraction areas located near the downgradient edge of the plume. The location of the three extraction areas was changed so that these extraction areas were situated closer to 19th Street wellfield. The extraction for the 19th Street wellfield was as follows:

- For the 5-year period between January 1986 to December 1990, normal pumping rates were used; and
- For the next 30 years, constant daily pumping of 1500 gpm from each of 19th Street No. 1 and No. 2 wells was used.

The extraction in the three extraction areas were:

- No pumping the first 5-year period; and
- For the next 30 years, constant daily pumping of 1000, 2000 and 1000 gpm from the extraction areas.

Figures 12-6 and 12-7 show the head contours and pathlines of imaginary particles for layers 1 and 2, respectively. Most of the imaginary particles were captured by the three extraction areas and the 19th Street wellfield. But a few imaginary particles near the south and one particle north of the three extraction areas were not captured.

Extraction Scenario No. 5

Extraction scenario no. 5 consisted of extraction from 19th Street wellfield and four extraction areas located near the downgradient edge of the plume. The extraction from the 19th Street wellfield was as follows:

- For the 5-year period between January 1986 to December 1990, normal pumping rates were used; and
- For the next 30-year period, constant daily pumping of 1500 gpm from 19th Street No. 1 and No. 2 wells was used.

The extraction in the four extraction areas were:

- No pumping the first 5-year period; and
- For the next 30 years, constant daily pumping of 1000, 1500, and 1000 and 1000 gpm from the four extraction areas.

Figures 12-8 and 12-9 show the head contours and pathlines of imaginary particles for layers 1 and 2, respectively. Some of the particles were captured by the extraction wells. A few particles south and north of the extraction areas were not captured. Also, a few particles escaped between the four extraction areas.

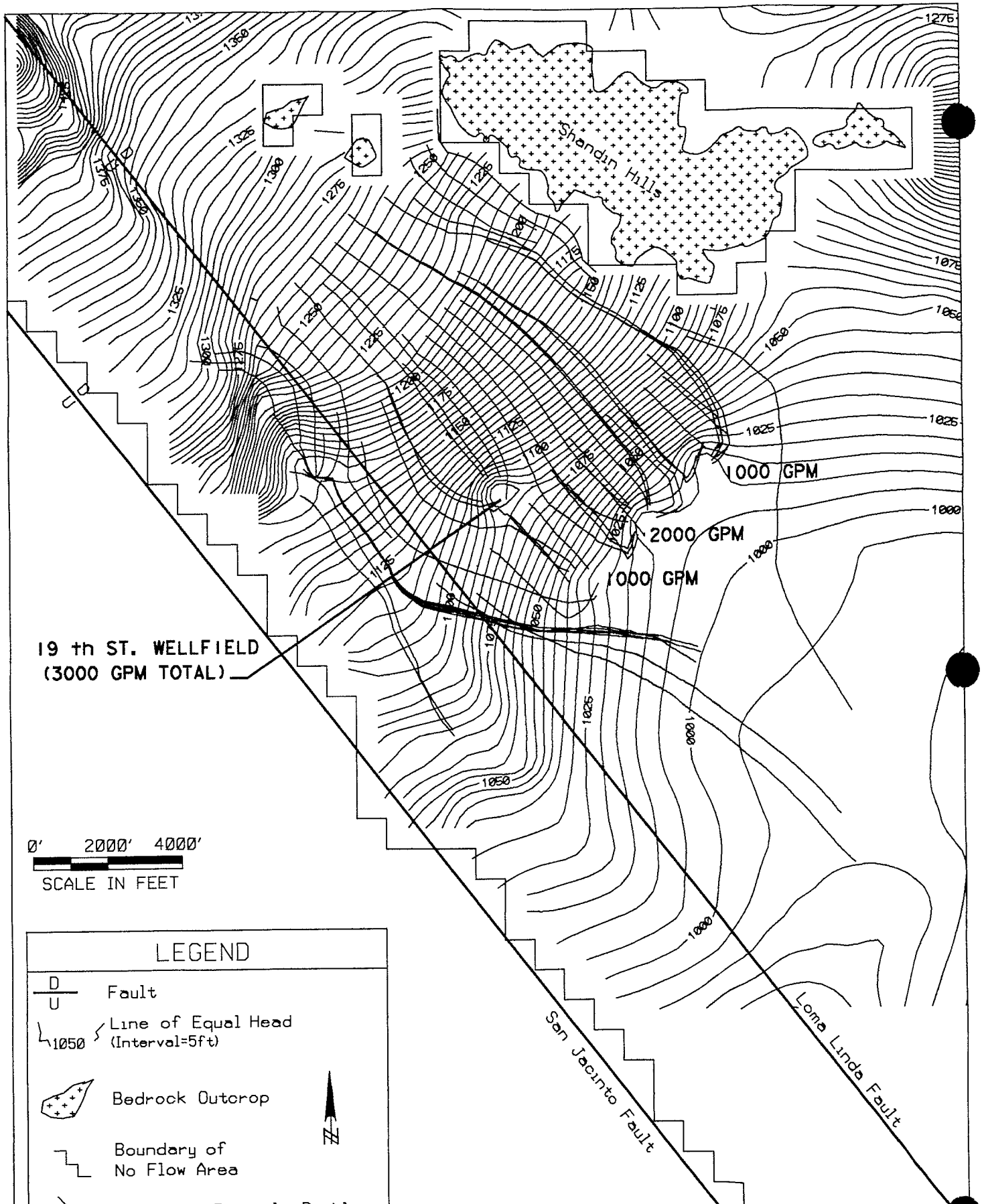

FIGURE 12-6

HEAD CONTOUR AND PATHLINE PLOT FOR EXTRACTION SCENARIO NO. 4 LAYER 1 (UPPER AQUIFER)

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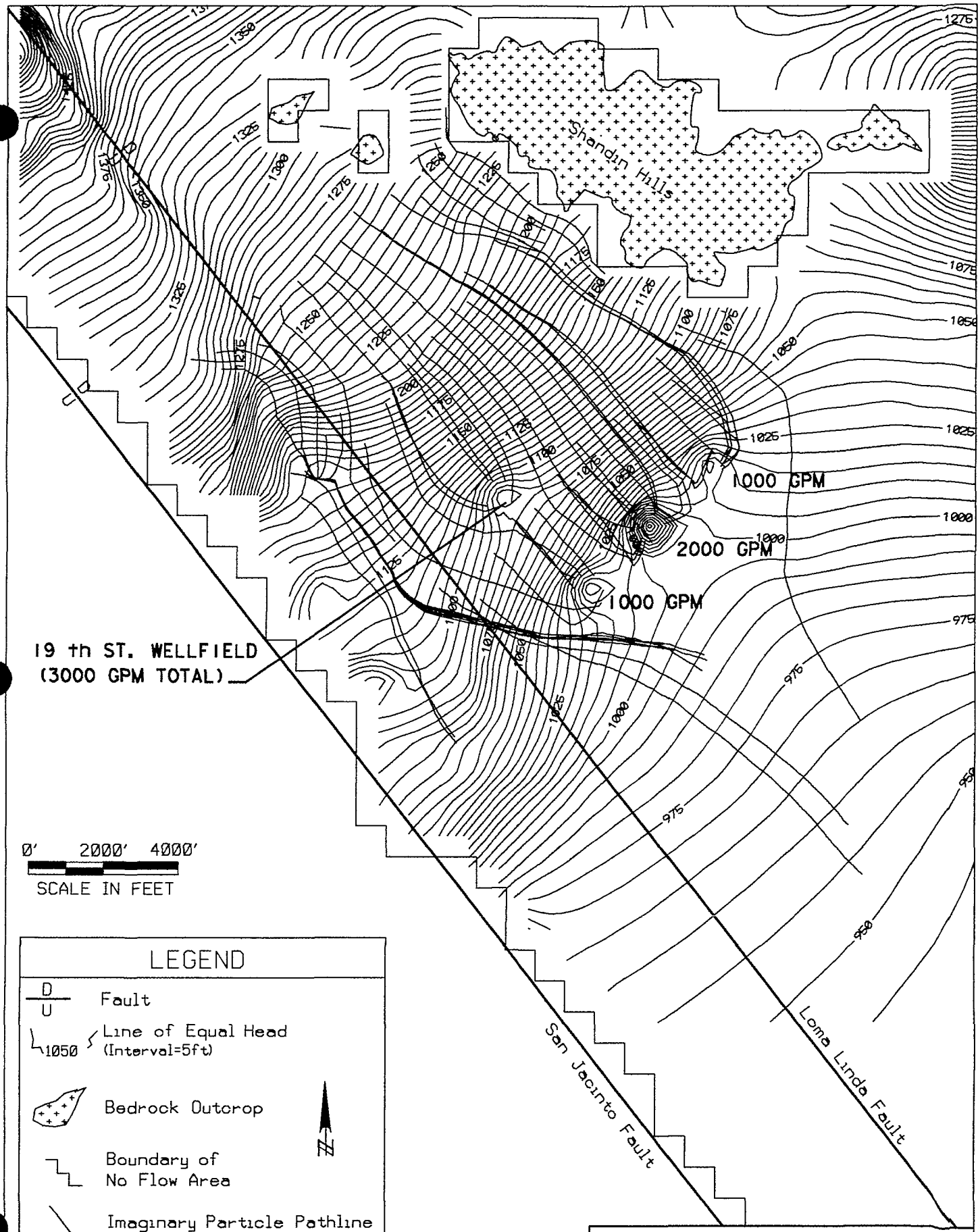

FIGURE 12-7

HEAD CONTOUR AND PATHLINE PLOT FOR EXTRACTION SCENARIO NO. 4 LAYER 2 (LOWER AQUIFER)

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